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Performance programming technology; performance effectiveness; physiological status; urinalysis; stress; productivity; emotional reactions.

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Volunteer subjects have participated in a series of experimental group missions involving continuous residence for varying periods in the programmed environment. The methodology involved in these ongoing studies extends the applications of performance programming technologies detailed in prior publications. The experiments focus upon an explicit analysis of the conditions under which interrelationships between participants and experimenters influence performance effectiveness. To assess potential interrelationships between physiological

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status and performance effectiveness and productivity, four measures were obtained while subjects concurrently operated the performance battery: 1) heart rate, 2) frontalis EMG, 3) skin temperature, and 4) skin conductance. Urine free cortisol levels were also determined from analyses of total urine volume which was collected throughout the mission. A strong overall relationship was observed between individual productivity and mean daily urine free cortisol. These observations together suggest that the stress of sustained high productivity along with prolonged performance accuracy on a demanding task may render an individual vulnerable to disruptive emotional reactions such as those provoked by the avoidance phase of the study.

THE JOHNS HOPKINS UNIVERSITY

EXTENDED ANALYSIS OF SMALL GROUP PERFORMANCE
AND THE
EFFECTS OF CONTINGENCY MANAGEMENT
IN A
PROGRAMMED ENVIRONMENT

TECHNICAL REPORT
NO. 4

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Baltimore, Maryland 21218

INTRODUCTION

Requirements for high levels of human performance in the unfamiliar and stressful environments necessitate the development of research-based technological procedures for maximizing the probability of effective and successful functioning at all levels of personnel participation. In furtherance of the objectives imposed by these requirements for improved selection, training, performance monitoring, and corrective procedures appropriate to operational participants, a research project was initiated to investigate small group performance under conditions of isolation and confinement during extended residence in a continuously programmed environment. The major objectives of this research have focused upon both the development of principles and procedures relevant to improvement of selection and training methods for personnel participating in operational missions and related organizational performance programs and the evaluation of preventive monitoring and corrective procedures to enhance mission performance and to provide appropriate countermeasures for the potentially disruptive effects of unfamiliar and/or stressful environments.

In approaching these objectives, a laboratory facility for the conduct of small group experiments with human volunteer subjects has been designed and constructed. Environmental control and programming principles have been conducted. A behavioral program has been developed and evaluated, and investigations have been conducted to optimize the temporal, sequential, and contingent relationships which enhance habitability and performance productivity. Particular attention has been directed to the analysis of social behavior under such conditions, and special mission demands are being investigated as they relate to the evaluation and management of inter- and intrapersonal stress and the development of effective stress countermeasures. Investigations of physiological correlates of behavior will provide more sensitive indicators of variations in mission task performance and predictive signs of impending performance decrements.

RESEARCH METHODS AND OUTCOME

Volunteer subjects have participated in a series of experimental group missions involving continuous residence for varying periods in the programmed environment. Early studies involved simply confinement and isolation of two-person groups for relatively brief 24-hour periods to demonstrate the adequacy of the hardware and to determine habitability under conditions which required only minimal, and basically biological, activity sequences, e.g., eating, sleeping, group interactions, etc. The major findings and conclusions were that the hardware was operational and the experimental setting capable of sustaining stress-free living conditions for at least these brief 24-hour periods. The second phase of the research involved extending the length of these studies from 1 to 3, and then to 10 days of continuous residence in the laboratory and introducing programmatic sequencies of performance activities. The major findings and conclusions were not only that such small groups could be maintained under stress-free living conditions for these more extended periods in the experimental environment, but also that the sequential con-

tingency performance program was supportive of both individual and group behavioral productivity.

Subsequent program parameter studies focused upon the temporal determinants of group productivity and effectiveness under conditions of performance schedule "pacing", i.e., imposed delays between activities, and of mission extensions of up to sixteen days of continuous residence in the laboratory. The major findings and conclusions emphasized the differential importance of selected components of the program, e.g., social activities, in maintaining individual and group performance effectiveness and the sensitivity of the behavioral program to reversible experimental manipulations, i.e., corrective countermeasures, in the course of extended residential missions. More recent studies have focused upon both differential program requirements for social cooperation in groups of three participants and effects on selected performance components of the mission activity schedule. The major findings and conclusions which emerged from a comparison of reversible cooperation and non-cooperation conditions emphasized the potentiating effects of such contingency management procedures upon group cooperative performance, on the one hand, and the group fragmentation which developed, i.e., subject pairing and individual social isolation, on the other. Perhaps most importantly, the results strongly suggested that cooperative programming contingencies can effectively prevent withdrawal or alienation of a potential social isolate from essential and productive group activities.

Group performance cohesiveness studies were then undertaken to investigate variations in the number of group members, i.e., two of three or three of three, permitted to interact socially under different program conditions. Comparisons between these conditions revealed marked differences in the degree to which program synchrony could be maintained, with considerably more drift separating individual subject schedules under dyadic than triadic conditions. In addition, individual social distance measures derived from observations of triadic episodes were predictive of the degree to which a given member would become socially isolated under dyadic programming conditions which limited social interactions to only two members of the group. In general, low group cohesiveness appeared to increase vulnerability to social fragmentation in the absence of specifically programmed triadic cooperation contingencies.

Performance program "chaining" sequence studies were then initiated to vary the degree to which the scheduling of activity components in the performance program was determined by the group participants or by a predetermined chaining sequence. The outcomes of these studies in terms of significant departures from the performance program and differential distributions of selected activities, e.g., social activities, under non-chaining conditions with limited sequential interdependencies among performance requirements emphasized the importance of participant - experimenter interactions, and they provided the transition to a series of special mission studies.

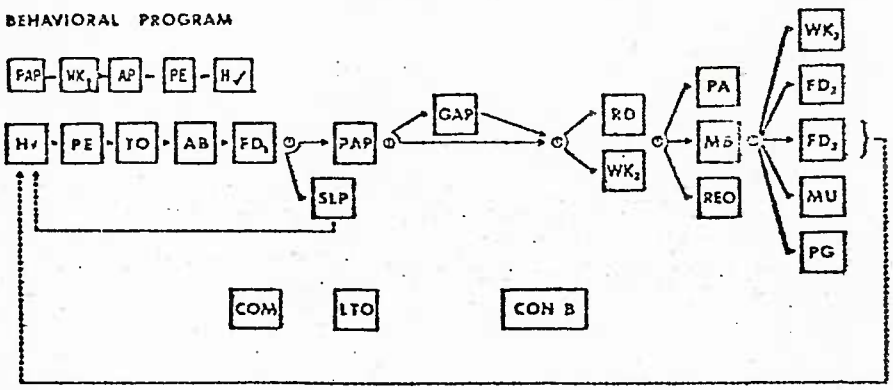
The methodology involved in these ongoing studies extends the applications of performance programming technologies detailed in the publications cited at the end of this report. The major procedural departure represented by the currently ongoing studies involved the introduction of a "work unit" completion contingency which determined the amount of group remuneration for participation in the study. In all previous studies, volunteer subjects

received a fixed per diem allowance for participation in the experiments irrespective of their performance. In contrast, these most recent studies provide a predetermined amount of remuneration for each completed work unit by individual team members in the form of a contribution to a group account, with group earnings divided evenly among the participants upon completion of the study. The objective of this innovative modification in the program was to generate a performance-consequence relationship between participants and experimenters superimposed upon the intrinsic motivational properties of the established behavioral schedule, and thereby to enhance the relevance of these studies to actual operational conditions. Under such circumstances, the experiments to be described focus upon an explicit analysis of the conditions under which these interrelationships between participants and experimenters influence performance effectiveness.

Figure 1 presents a schematic diagram of the performance program used in the most recent series of four 6 to 12 day experiments. Although the basic fixed and optional components of the program as described in previous publications continued to be in effect, for three groups (Groups 1-3) the following sequence of five work unit activities was made available independently of the remaining sequentially arranged activities: (1) Private Arithmetic Problems (PAP), requiring 200 correct solutions; (2) Work One (WK1), requiring 5000 lever operations; (3) Arithmetic Problems (AP), requiring 50 correct solutions; (4) Physical Exercise (PE), requiring 500 correct presses; and (5) Health Check (H ✓), requiring completion of the health assessment battery. The work unit was programmed for concurrent availability in each private room, and it could be selected upon completion of any activity within the full behavioral program. Once a work unit had been selected, all five activities had to be completed before the subject could resume the behavioral program at the location where the work unit was voluntarily initiated. During a work unit, the Communication activity was unavailable, and subjects were not permitted to use the tape player for music. Parameters were chosen so that completion of a work sequence required 1 - 1.5 hours.

For Group 4, much more sophisticated performance requirements were introduced in place of the work-unit sequence. A room in the programmed environment was dedicated as a duty station which contained computer peripheral devices displaying a multiple task performance battery (MTPB) that determined on-duty performance. This "synthetic work" performance battery is composed of the following five task components which are presented concurrently to an operator and which represent major dimensions of complex human performance capabilities: (1) probability monitoring, (2) arithmetic operations, (3) target identification, (4) static signal-state changes, and (5) dynamic signal-state changes. Since only a single operator may be present in the assigned area, this duty station format fosters around-the-clock operation of the performance battery and accordingly simulates situations requiring a group to be continuously operational with respect to critical mission demands. Parameters were chosen so that the accumulation of 600 MTPB accuracy points required 1 - 1.5 hours.

The consequences of completing the various work tasks were systematically varied to assess the effects of alternative work performance-consequence relationships between the participants and the experimenters. Throughout the first several days of a mission, a positive, i.e., appetitive, relationship



INVENTORY OF ACTIVITIES

NOTATION	FULL NAME	BRIEF DESCRIPTION
H✓	HEALTH CHECK	TEMPERATURE, PULSE, WEIGHT, STATUS REPORT
PE	PHYSICAL EXERCISE	300 CORRECT PRESSES ON AUTOMATED TASK
TO	TOILET OPERATIONS	USE OF PRIVATE BATHROOM AND CONTENTS OF DRAWER CONTAINING TOILETRIES
AB	AUTOGENIC BEHAVIOR	RELAXATION EXERCISES ON CASSETTE TAPE
FD1	FOOD ONE	TWO SELECTIONS FROM A LIST OF LIGHT FOODS
SLP	SLEEP	USE OF BED AND PRIVACY CURTAIN
PAP	PRIVATE ARITHMETIC PROBLEMS	150 CORRECT SOLUTIONS OF ARITHMETIC PROBLEMS
GAP	GROUP ARITHMETIC PROBLEMS	OPTIONAL, CONTRIBUTE CORRECT SOLUTIONS OF PROBLEMS TO GROUP RATIO CRITERION
RD	READING	ACCESS TO BOOK
WK2	WORK TWO	PROBLEMS, EXPERIMENTS, ASSEMBLY PROJECTS
PA	PUZZLE ASSEMBLY	ASSEMBLE A PUZZLE
MB	MANUAL BEHAVIOR	ACCESS TO ART MATERIALS
REQ	REQUISITION	EARN DELAYED DELIVERY OF TREATS
WK3	WORK THREE	ACCESS TO WORKSHOP
FD2	FOOD TWO	PRIVATE MAJOR MEAL
FD3	FOOD THREE	MAJOR MEAL IN RECREATION ROOM, GAMES
MU	MUSIC	EARN A CASSETTE TAPE
PG	PRIVATE GAMES	ACCESS TO SOLITARY GAMES
COM	COMMUNICATION	ACCESS TO INTERCOM
LTO	LIMITED TOILET OPERATIONS	ACCESS TO ESSENTIAL TOILET FACILITIES
CON B	CONDITION B	CHANGE IN PROGRAM CONDITION

Figure 1. A schematic diagram of the performance program.

was in effect whereby group members' completion of a work unit or MTPB points produced deposits to a group account, the proceeds of which were equally divided among the participants at the conclusion of the study. Throughout the next several days of a study, a negative, i.e., avoidance, relationship was in effect such that work no longer produced increments in the group account, but rather were required of the participants in order to avoid withdrawals of similar magnitude. That is, work performance requirements for avoidance days provided that withdrawals be made from the group account for uncompleted work below an assigned daily total, e.g., 20 units or 10,000 MTPB points, determined on the basis of the group productivity records during the first several days, i.e., the average number of work sequences or MTPB points completed per 24 hours. This group requirement could be satisfied under any conditions of individual work scheduling or distribution decided upon by the participants. Finally, the last days of a study were programmed as a reversal to those conditions in effect during the first several appetitive days of the study, with the exception of Group 2 noted below. For Groups 1 through 4, the appetitive (AP) and avoidance (AV) conditions were in effect in the following order and number of successive days under each condition, respectively: AP-AV-AP (4,4,3), AP-AV-AP-AV (3,3,3,3). AP-AV-AP (3,6,3), and AP-AV-AP (2,3,1).

The performance-consequence contingency maintained substantial overall productivity levels for all subjects in each group within the course of the several studies. Figure 2 presents the total number of work units (Groups 1-3) and Table 1 the total MTPB points earned (Group 4) for all subjects in each group across successive experimental days. In Groups 1-3, no member completed fewer than two work units per day (e.g., Subject 1 on day 1) with a range of 2 to 16 units. In Group 4, which operated the performance battery, the range of daily productivity levels, at least when all participants worked, was 2000 to 5648 points, representing approximately 3 to 9 hours of work.

Within Groups 1-3, the work unit outputs were more evenly distributed among subjects during the avoidance condition in comparison to such distributions during the appetitive condition. A comparison of the differences between the highest and lowest work unit frequency for all subjects within these groups, under the assumption that such differences approach zero when variability is absent, between the two conditions showed a significant effect ($t=2.07$, $df=28$, $p < .05$). These distributions were a function of social pressures, to be explained below, by high-productivity individuals who were intolerant of output variations during the avoidance condition.

Group 4 was the only group which had a member who failed to work during a 24-hour period. On day 5, the second day of the avoidance condition, a crisis occurred within this group which not only resulted in "mutinous" withdrawal from duty by a subject, but also threatened the group's capacity to complete its mission, i.e., completion of the assigned daily work. On that second day of the avoidance condition, Subject 3 fell behind in his typical performance productivity by a magnitude of less than 2 percent of the assigned daily group criterion. Unlike a high-productivity subject's tolerance of variations in productivity during the appetitive condition, this subject (Subject 1) became openly and vehemently hostile at this relatively trivial shortcoming, and he displayed verbal aggression toward his teammates. Importantly, Subject 1 refused to perform any further work during

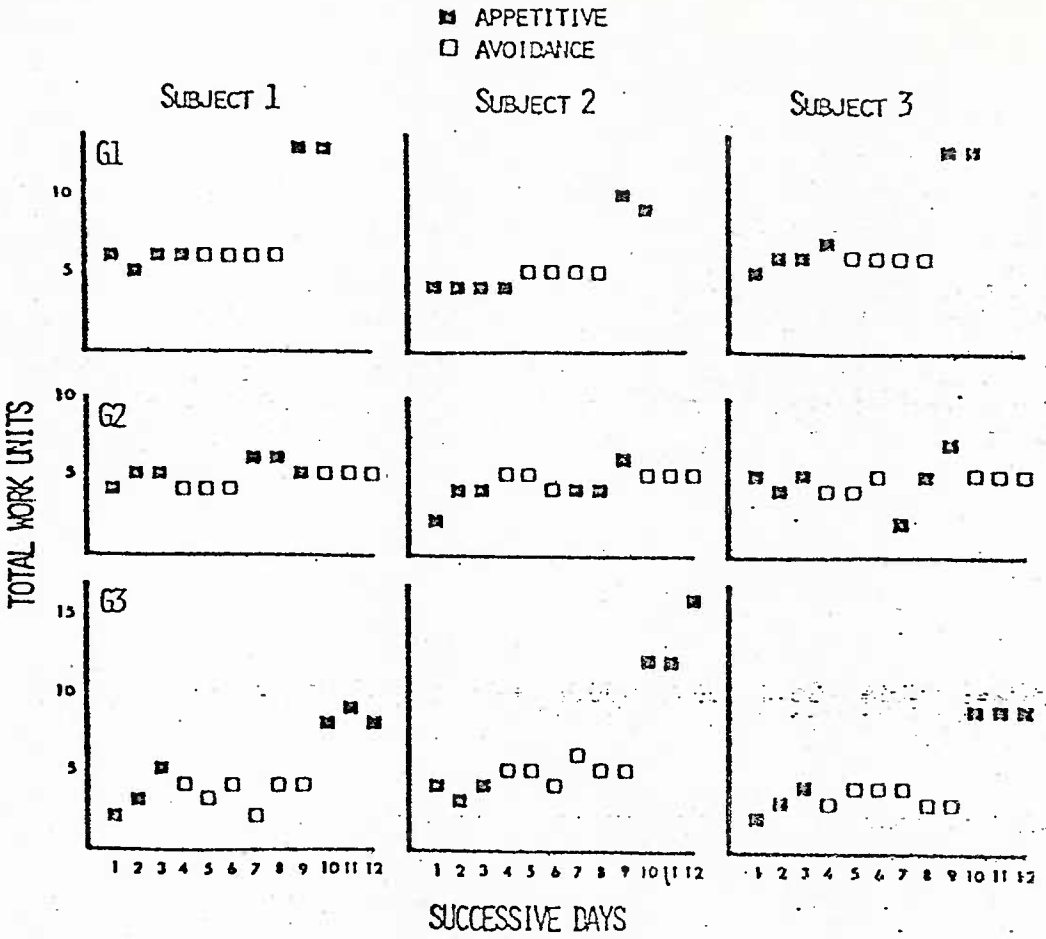


Figure 2. Total work units for all subjects in Groups 1 - 3 across successive experimental days.

TABLE 1

TOTAL MTPB POINTS PER DAY

Subject	Successive Days					
	1	2	3	4	5	6
1	4154	4221	4388+	4627+	0+	5648
2	3927	4381	4437+	4810+	2450+	5023
3	2000	4126	3966+	3207+	3755+	4487

+Avoidance day

the avoidance condition, although the duration of the avoidance condition was not known by the group, and on day 5, the group lost heavily in potential earnings as a result of insufficient personnel to operate the duty station on a continuous and efficient basis.

Disruption in group cohesion during the avoidance condition was not limited to Group 4. During each Health Check activity, each subject responded on a 4-point scale reflecting "degree of irritation" (1=none to 4=extreme) with the other two participants. Table 2 presents mean ratings of such interpersonal irritation for all subject-paired combinations within each group across successive experimental days. Intermember expressions of irritation during avoidance conditions were most pronounced in Group 1 and Group 4. Significantly, in both of these groups crisis situations were related to a member whose productivity levels, at least during the avoidance conditions, were somehat less than those of his teammates, e.g., Subject 2 in Group 1, Subject 3 in Group 4. In Group 1, Subject 2, the low-productivity member, was rejected by the group on day 7, the third day of the avoidance condition, and he was isolated from social interactions for the remaining days of the study. These data are shown in Figure 3 which shows durations of dyadic and triadic social episodes across successive days of the study. Importantly, despite these crisis situations observed during the avoidance conditions, group members in both Groups 1 and 4 showed a reduction in at least expressed interpersonal irritation when the appetitive condition was reintroduced as the final phase of the study.

The results with Group 4, in which a participant failed to work on day 5, confirm and extend the outcomes of the previous three evaluations of avoidance schedules, and they further suggest that where performance requirements are continuous, realistic, and demanding under such conditions, a group may fail to complete its assigned mission. However, although the experimental protocol provided for only one appetitive day to follow the avoidance condition in Group 4, this brief period was sufficient to reveal partial recovery of group cohesiveness and individual productivity on the duty station. Intermember tensions declined, and the mutinous team member was reintegrated into the performance schedule, resuming his previous productivity levels. Significantly, performance productivity and on-duty performance effectiveness for Group 4 were highest during the last appetitive day of the study, as they were for Group 1.

The expressed opinions and emotional attitudes of the group directed to the behavioral program and to the experimenters differed significantly between the appetitive and avoidance conditions. During each Health Check activity, each subject responded on a 4-point scale reflecting "degree of irritation" (1=none to 4=extreme) with the behavioral program and the experimenters. Tables 3 and 4 present mean ratings on these scales for all subjects in each group across successive experimental days. With respect to the behavioral program, all subjects in each group showed the highest daily ratings during the avoidance condition, and for a pooled analysis, mean ratings were significantly higher during the avoidance condition in comparison to corresponding ratings of the appetitive condition ($t=9.47$, $df=114$, $p < .001$). With respect to the experimenters, seven of the twelve subjects showed the highest daily ratings during the avoidance condition, and for a pooled analysis, mean ratings were significantly higher during avoidance conditions in comparison to corresponding appetitive conditions

TABLE 2

MEAN INTERPERSONAL RATINGS PER DAY

		Successive Days											
		1	2	3	4	5	6	7	8	9	10	11	12
	S2	1.08	1.00	1.09	1.17	1.20+	1.00+	1.00+	1.00+	1.13	1.31		
S1	S3	1.00	1.08	1.00	1.17	1.00+	1.00+	1.00+	1.00+	1.00	1.06		
	S1	1.00	1.00	1.00	1.00	1.00+	1.80+	2.00+	2.00+	1.85	1.82		
S2	S3	1.00	1.00	1.00	1.38	1.11+	2.40+	4.00+	3.89+	2.46	2.27		
	S1	1.00	1.00	1.00	1.00	1.00+	1.00+	1.00+	1.00+	1.00	1.00		
S3	S2	2.00	2.10	2.00	2.17	1.91+	2.70+	3.00+	1.20+	1.37	2.07		
	S2	1.00	1.00	1.00	1.00+	1.57+	1.38+	1.11	1.20	1.00	1.00+	1.00+	
S1	S3	1.00	1.00	1.00	1.00+	1.00+	1.00+	1.00	1.00	1.00	1.00+	1.00+	
	S1	1.25	1.1[illegible]	1.00	1.00+	1.00+	1.00+	1.00	1.00	1.00	1.00+	1.00+	1.00+
S2	S3	1.00	1.50	1.00	1.00+	1.00+	1.00+	1.00	1.00	1.00	1.00+	1.00+	1.00+
	S1	1.11	1.00	1.00	1.00+	1.00+	1.00+	1.00	1.29	1.00	1.00+	1.00+	1.00+
S3	S2	1.67	1.14	1.29	1.00+	1.00+	1.25+	1.80	1.29	1.10	1.13+	1.00+	1.00+
	S2	1.00	1.00	1.00	1.00+	1.00+	1.00+	1.00+	1.00+	1.00+	1.00	1.00	1.00
S1	S3	1.00	1.00	1.00	1.00+	1.00+	1.00+	1.00+	1.00+	1.00+	1.00	1.00	1.00
	S1	1.00	1.00	1.00	1.00+	1.00+	1.00+	1.00+	1.00+	1.00+	1.00	1.00	1.00
S2	S3	1.00	1.00	1.00	1.00+	1.00+	1.00+	1.00+	1.00+	1.00+	1.00	1.00	1.00
	S1	1.00	1.00	1.00	1.00+	1.00+	1.00+	1.00+	1.00+	1.00+	1.00	1.00	1.00
S3	S2	1.00	1.00	1.00	1.00+	1.00+	1.00+	1.00+	1.00+	1.00+	1.00	1.00	1.00
	S2	1.33	1.50	1.00+	1.00+	1.00+	1.00						
S1	S3	1.33	2.00	2.33+	2.00+	2.60+	2.00						
	S1	1.00	1.00	1.00+	1.00+	1.00+	1.00						
S2	S3	1.00	1.00	2.33+	1.00+	1.00+	1.00						
	S1	1.00	1.00	1.00+	1.00+	2.33+	1.50						
S3	S2	1.33	1.50	1.00+	1.00+	1.00+	1.00						

+Avoidance day.

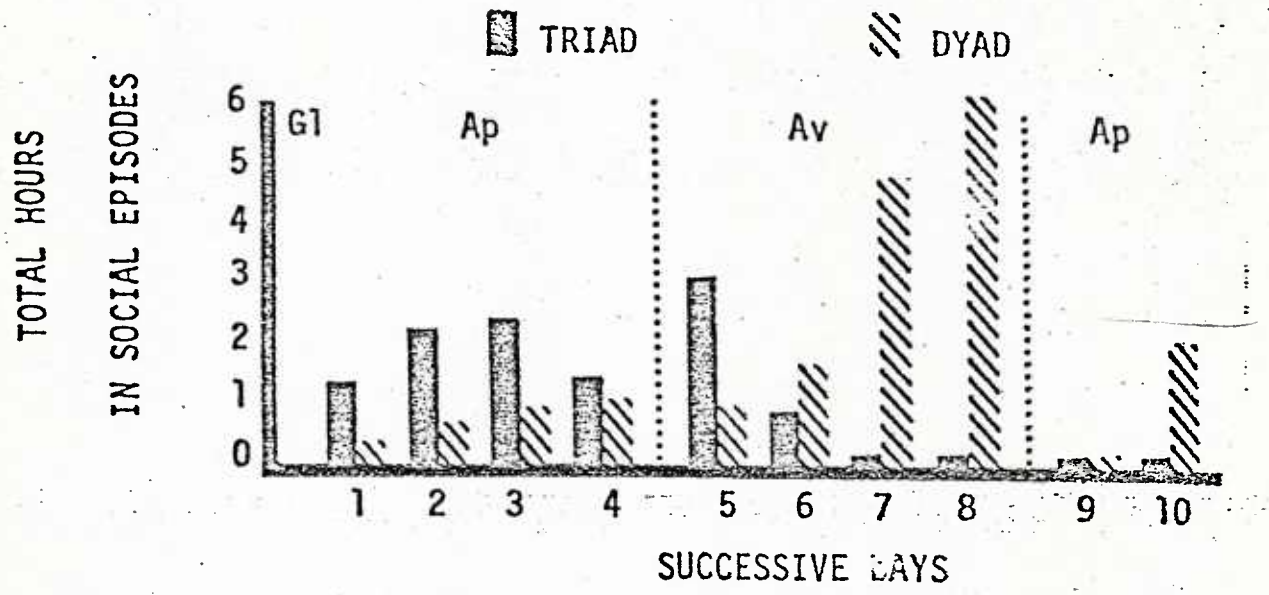


Figure 3. Durations of triadic and dyadic social episodes across successive experimental days for subjects in Group 1.

TABLE 3

MEAN RATINGS OF THE BEHAVIORAL PROGRAM PER DAY

		Successive Days											
		1	2	3	4	5	6	7	8	9	10	11	12
G1	S1	1.00	1.00	1.00	1.00	1.00+	1.17+	4.00+	4.00+	1.00	1.00		
	S2	1.00	1.00	1.00	1.00	2.88+	3.80+	4.00+	4.00+	1.00	1.00		
	S3	1.00	1.00	1.00	1.00	2.00+	2.10+	3.00+	3.20+	1.00	1.00		
G2	S1	1.00	1.00	1.00	4.00+	4.00+	4.00+	1.00	1.00	1.00	4.00+	4.00+	*
	S2	1.60	1.71	1.14	2.63+	3.00+	3.00+	1.00	1.00	1.00	3.25+	3.38+	3.56+
	S3	1.00	1.00	1.00	2.00+	1.86+	2.63+	1.00	1.29	1.00	1.25+	3.43+	3.29+
G3	S1	1.00	1.00	1.00	3.33+	1.67+	1.00+	1.33+	1.00+	1.00+	1.67	1.67	1.33
	S2	1.00	1.00	1.00	1.00+	1.00+	1.67+	1.75+	2.17+	2.00+	1.00	1.00	1.00
	S3	1.00	1.00	1.00	2.00+	1.33+	1.33+	1.25+	1.33+	1.00+	1.25	1.67	1.60
G4	S1	1.00	1.00	1.00+	1.67+	4.00+	1.00						
	S2	1.00	1.00	1.67+	2.67+	3.50+	1.00						
	S3	1.00	1.00	1.67+	2.00+	3.00+	1.00						

+Avoidance day
*The subject refused to complete the Health Check activity.

TABLE 4

MEAN RATINGS OF THE EXPERIMENTERS PER DAY

		Successive Days											
		1	2	3	4	5	6	7	8	9	10	11	12
G1	S1	1.00	1.00	1.00	1.00	1.00+	1.00+	2.55+	1.56+	1.00	1.00		
	S2	1.00	1.00	1.00	1.00	1.00+	1.00+	1.00+	1.00+	1.00	1.00		
	S3	1.00	1.00	1.00	1.00	1.09+	1.20+	1.60+	2.80+	1.11	1.00		
G2	S1	1.00	1.00	1.00	1.43+	1.14+	1.00+	1.00	1.00	1.00	1.11+	4.00+	*
	S2	1.00	1.00	1.00	1.14+	1.00+	1.00+	1.00	1.00	1.25	1.38+	2.00+	1.33+
	S3	1.00	1.00	1.00	1.00+	1.00+	1.00+	1.00	1.14	1.60	1.00+	3.00+	3.57+
G3	S1	1.00	1.00	1.00	1.00+	1.00+	1.00+	1.67+	1.00+	1.00+	1.00	2.33	1.00
	S2	1.00	1.00	1.00	1.00+	1.00+	1.00+	1.00+	1.33+	1.00+	1.00	1.00	1.00
	S3	1.00	1.00	1.00	1.67+	1.00+	1.00+	1.00+	1.00+	1.00+	1.00	1.00	1.40
G4	S1	1.00	1.00	1.67+	1.00+	3.60+	3.00						
	S2	1.00	1.00	1.00+	1.00+	1.00+	1.33						
	S3	1.00	1.00	1.00+	1.00+	1.00+	1.00						

+Avoidance day
*The subject refused to complete the Health Check activity.

($t=2.72$, $df=117$, $p < .01$). In effect, then, the avoidance condition produced emotional displeasure with the behavioral program and with the experimenters who were perceived as responsible for allowing this aversive work situation to continue.

With respect to the more intra-personal aspects of these program condition effects, subjects reported mood changes between the program conditions on the Depression factor of the Lorr's Mood Scale which was also administered during each Health Check activity. Table 5 presents mean depression ratings for all subjects in each group across successive experimental days. Eleven of the twelve subjects showed the highest daily rating during the avoidance condition, and for a pooled analysis, mean depression ratings were significantly higher during avoidance conditions in comparison to corresponding appetitive conditions ($t=3.95$, $df=117$, $p < .001$). Because similar changes have not been observed to occur in previous studies as a function of "time-within-the chamber", these differences may be confidently attributable to effects of the two program conditions. Finally, recovery to pre-avoidance levels of such mood ratings during the final appetitive days of a study (Group 2 was the exception), where extraordinary work output was observed, substantiates the conclusion that high productivity itself need not be a cause of dysphoric mood or strained subject-experimenter interactions.

Performance on the several component tasks of the work unit was not differentially influenced by the two program conditions. Figure 4 presents mean performance per trial for all subjects in Group 1 across successive program conditions for each work task. Both mean errors per trial and mean latency for correct answers per trial are presented for Private Arithmetic Problems (PAP) and Arithmetic Problems (AP). The most striking consistency in these data is the absence of notable condition effects on any work task for any subject in this group. With the exception of PAP and AP errors for Subject 1 and of PE errors for Subject 2, all performance measures show small, but consistent, improvements throughout the course of the study.

Similar performance trends were observed on the components of the MTPB for Group 4. Tables 6, 7, and 8 present these data for Subjects 1, 2, and 3, respectively, across several consecutive half-hour observational intervals. One such interval occurred during the second half hour of work when a high performance probe was in effect such that signal or task misses and errors produced a substantial reduction in accuracy points. Throughout the remaining intervals of work, whose total duration was determined by the operator's preference, only false alarms diminished accuracy-point accumulations.

These data show that all tasks within the battery were performed by each subject during any given interval presented. Additionally, errorless performance was never observed, showing that the battery and its associated parameters continued to challenge the subjects even after many hours of practice. However, performance accuracy was sensitive to the demands of the high performance probe (HPP). During the HPP, all subjects show an increase in the frequency of false alarms on the probability monitoring task (D), perhaps the most difficult task in the battery to operate correctly. Furthermore, Subjects 1 and 3 show a striking increase in failures to respond (i.e., signal misses) on the target identification task (T). In summary, then, MTPB performance accuracy was not differentially affected by the two program conditions, although its vulnerability to change, if not disruption,

TABLE 5

MEAN DEPRESSION RATINGS PER DAY

		Successive Days											
		1	2	3	4	5	6	7	8	9	10	11	12
G1	S1	8.08	8.42	8.18	8.00	8.10+	8.25+	9.55+	11.33+	8.00	8.00		
	S2	8.75	8.78	8.11	8.38	9.11+	11.20+	11.33+	12.56+	8.08	9.09		
	S3	8.17	9.27	8.33	8.25	8.18+	9.60+	10.60+	13.70+	10.84	8.80		
G2	S1	8.43	9.63	9.88	10.43+	9.88+	10.00+	10.00	10.00	9.50	10.44+	10.38+	*
	S2	10.40	8.86	8.43	8.25+	8.25+	8.29+	8.86	8.57	8.00	8.25+	8.00+	8.33+
	S3	8.67	9.43	9.29	9.38+	8.57+	8.38+	8.20	8.71	8.11	8.38+	11.43+	11.33+
G3	S1	8.00	9.00	9.00	9.67+	10.00+	9.80+	10.33+	9.67+	12.00+	9.00	9.00	9.67
	S2	8.80	8.83	8.50	9.20+	8.66+	8.66+	8.25+	10.17+	9.80+	8.33	9.00	9.67
	S3	8.60	8.00	8.25	8.00+	8.00+	8.00+	8.00+	8.00+	10.00+	9.00	8.00	8.40
G4	S1	8.67	9.00	8.67+	8.00+	12.60+	8.50						
	S2	9.50	10.33	13.00+	13.33+	14.00+	10.33						
	S3	8.33	8.25	9.00+	8.75+	9.67+	10.00						

+Avoidance day
*The subject refused to complete the Health Check activity.

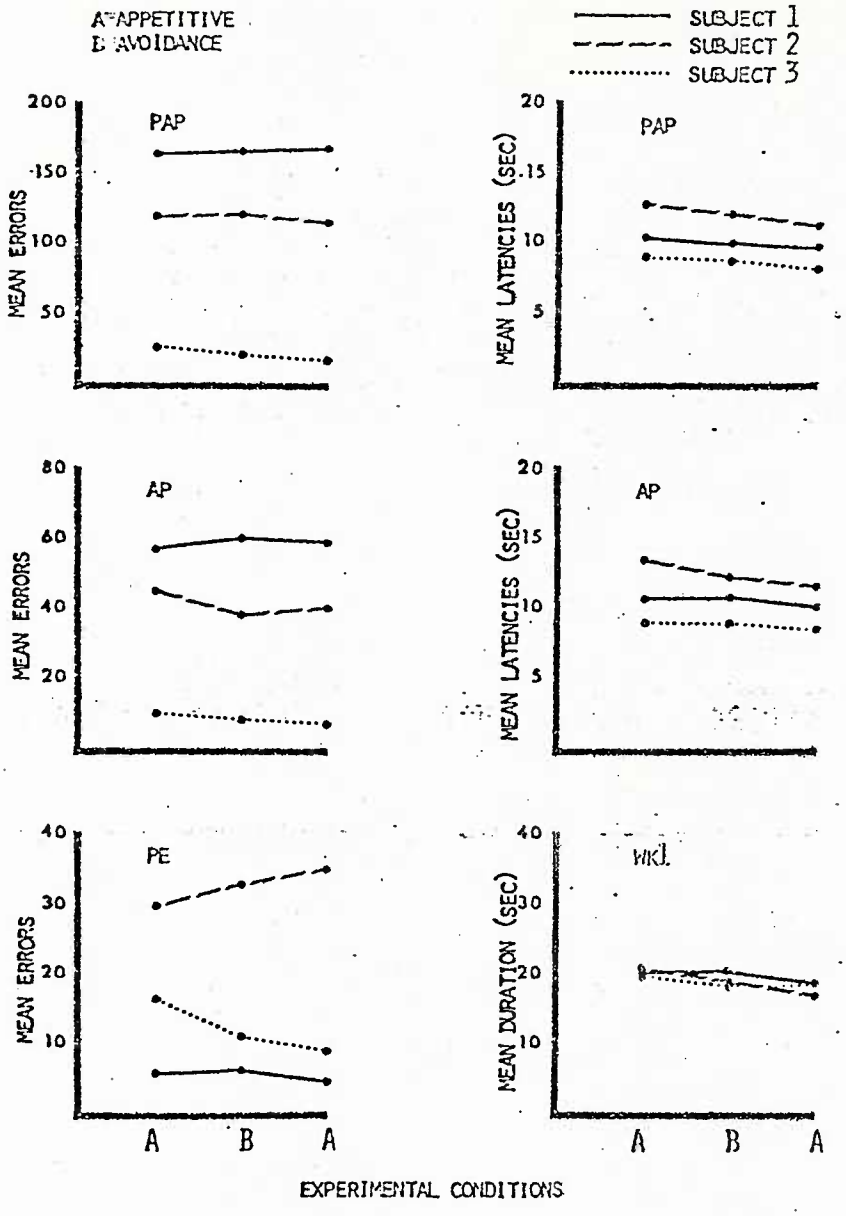


Figure 4. Mean performance per trial for all subject in Group 1 across successive program conditions for each work component.

TABLE 6

MTPB PERFORMANCE DATA FOR SUBJECT 1

		P				A				T			W				B			
		H	M	FA	L	R	W	M	L	R	W	M	H	M	FA	L	H	M	FA	L
AP	I.	34.9	9.5	14.3	51.2	56.5	3.5	0.0	11.7	24.0	4.0	0.0	87.5	0.0	0.3	1.0	32.8	1.5	3.3	8.1
	II.	48.3	4.0	33.0	39.9	55.5	4.3	0.3	11.6	15.5	2.0	10.5	92.3	0.3	2.3	0.7	34.5	2.3	4.5	7.4
	III.	32.3	12.0	18.0	44.1	56.0	4.0	0.0	11.8	23.0	4.3	0.8	89.3	1.0	0.5	1.1	34.8	1.3	2.5	7.7
	IV.	34.0	10.8	18.8	49.7	56.0	3.3	0.5	11.2	23.5	4.3	0.8	78.8	0.3	0.3	1.1	33.3	1.5	2.3	7.8
	Mean	37.4	9.1	21.0	46.2	56.0	3.8	0.2	11.6	21.5	3.7	3.0	87.0	0.4	0.9	1.0	33.9	1.7	3.2	7.8
AV	I.	41.8	6.5	21.0	39.9	56.3	3.8	0.0	11.6	23.3	3.5	1.3	87.8	0.0	0.0	1.0	33.5	1.0	2.3	7.5
	II.	53.5	1.8	34.5	37.0	57.5	2.5	0.0	11.8	22.5	2.8	2.8	83.8	0.3	3.3	0.6	32.5	2.0	1.8	8.2
	III.	47.3	3.8	22.5	43.6	56.8	3.3	0.0	11.7	23.3	4.8	0.3	84.3	0.3	0.3	1.0	33.5	0.8	2.0	8.5
	IV.	49.8	2.5	19.5	40.0	55.8	3.8	0.3	11.8	21.8	6.3	0.0	87.8	0.8	0.5	1.1	31.3	2.5	0.8	8.5
	Mean	48.1	3.7	24.4	40.1	56.6	3.4	0.1	11.7	22.7	4.4	1.1	85.9	0.4	1.0	0.9	32.7	1.6	1.7	8.2
AP	I.	54.5	1.0	11.5	32.0	53.0	6.5	0.0	12.6	24.0	9.0	0.0	87.5	0.0	0.5	1.0	34.5	1.0	4.0	9.3
	II.	54.5	1.0	17.5	37.9	53.5	6.5	0.0	12.0	22.5	3.5	2.0	83.0	0.0	3.0	0.7	32.0	2.5	2.5	8.6
	III.	56.0	1.0	26.5	30.1	57.5	2.5	0.0	12.8	22.0	5.0	1.0	96.5	0.0	0.5	1.0	33.0	2.0	0.5	9.3
	IV.	57.5	1.0	18.5	32.7	58.0	2.0	0.0	11.5	22.0	4.5	1.5	84.0	0.0	0.0	1.1	31.0	2.5	1.5	7.8
	Mean	55.6	1.0	18.5	33.2	55.5	4.4	0.0	12.2	22.6	5.5	1.1	87.5	0.0	1.0	1.0	32.6	2.0	2.1	8.8

P=probability monitoring, A=arithmetic operations, T=target identification, W=warning light monitoring, B=blinking light monitoring, H=hits, M=misses, FA=false alarms, L=latency in sec, R=right, and W=wrong. I=first half hour, II=second half hour of high performance probe, III=third half hour, and IV=last half hour of work. AP=appetitive condition means, and AV=avoidance condition means.

TABLE 7

MTPB PERFORMANCE DATA FOR SUBJECT 2

		P				A				T			W				B			
		H	M	FA	L	R	W	M	L	R	W	M	H	M	FA	L	H	M	FA	L
AP	I.	19.3	18.8	5.5	60.2	55.0	2.8	2.5	15.7	24.5	1.3	1.3	83.3	6.0	1.3	1.4	32.0	3.8	1.5	9.5
	II.	33.0	11.5	21.0	55.5	56.5	3.3	0.3	17.0	23.0	4.0	1.0	81.3	6.3	3.5	1.4	30.0	2.5	1.0	10.4
	III.	15.5	22.5	8.8	51.7	58.8	1.3	0.0	15.3	25.0	2.8	0.5	81.8	2.5	1.5	1.4	30.3	2.8	2.5	9.5
	IV.	4.3	31.0	1.0	66.7	55.3	2.7	2.3	16.4	23.3	3.0	1.7	74.3	12.3	2.7	1.5	29.7	3.3	1.0	11.8
	Mean	18.0	21.0	9.1	58.5	56.4	2.5	1.3	16.1	24.0	2.8	1.1	80.2	6.8	2.3	1.4	30.5	3.1	1.5	10.3
AV	I.	26.8	15.0	12.7	48.5	57.5	1.7	0.7	15.6	23.5	3.5	1.0	84.8	3.7	1.3	1.4	33.5	2.3	1.2	8.7
	II.	50.2	4.0	46.2	38.8	56.7	2.3	1.2	15.6	23.8	3.7	0.7	83.2	1.8	1.2	1.4	32.8	1.2	1.5	8.9
	III.	10.4	26.0	6.2	49.3	58.0	1.8	0.2	14.4	24.8	2.2	1.0	81.0	0.2	0.2	1.5	31.4	3.0	1.8	8.6
	IV.	8.0	26.8	3.8	59.5	54.8	2.4	0.4	14.2	22.2	4.0	1.0	76.8	2.0	1.2	1.5	31.0	2.0	0.6	8.3
	Mean	23.9	18.0	17.2	49.0	56.8	2.1	0.6	15.0	23.6	3.4	0.9	81.5	1.9	1.0	1.5	32.2	2.1	1.3	8.6
AP	I.	31.0	11.5	9.0	55.6	57.0	3.0	0.0	13.9	26.5	1.0	0.5	88.0	1.0	1.0	1.3	34.5	1.5	1.0	8.3
	II.	54.0	1.5	54.0	36.6	58.5	1.5	0.0	14.4	24.5	3.5	0.0	88.5	0.0	0.0	1.3	35.0	0.5	0.5	8.1
	III.	23.0	16.5	8.5	49.0	57.5	2.0	0.5	13.4	20.0	4.5	2.5	83.0	0.5	0.5	1.3	31.5	1.0	0.5	8.5
	IV.	9.5	28.0	5.5	52.3	55.5	4.0	0.0	13.6	23.0	4.0	1.0	96.0	1.5	1.0	1.5	33.5	1.0	0.0	7.7
	Mean	29.4	14.4	19.3	48.4	57.1	2.6	0.1	13.8	23.5	3.3	1.0	88.9	0.8	0.6	1.4	33.6	1.0	0.7	8.2

P=probability monitoring, A=arithmetic operations, T=target identification, W=warning light monitoring, B=blinking light monitoring, H=hits, M=misses, FA=false alarms, L=latency in sec, R=right, and W=wrong. I=first half hour, II=second half hour of high performance probe, III=third half hour, and IV=last half hour of work. AP=appetitive condition means, and AV=avoidance condition means.

TABLE 8

MTPB PERFORMANCE DATA FOR SUBJECT 3

		P				A				T			W				B			
		H	M	FA	L	R	W	M	L	R	W	M	H	M	FA	L	H	M	FA	L
AP	I.	38.3	6.0	21.3	46.8	55.7	3.3	1.0	14.2	21.0	5.3	2.0	88.0	1.7	1.3	1.1	29.7	3.3	0.7	10.7
	II.	49.0	4.7	59.0	35.7	53.0	5.3	1.7	15.3	7.0	1.7	19.3	87.0	1.0	0.7	1.1	34.3	1.7	1.0	9.1
	III.	38.0	8.0	19.7	45.5	55.0	4.0	1.0	14.0	22.0	2.3	3.7	80.7	1.0	0.0	1.1	32.0	3.3	1.3	9.7
	IV.	47.7	2.7	25.0	47.2	57.0	3.0	0.3	14.5	24.7	3.0	0.7	83.7	1.3	0.3	1.1	33.7	1.3	0.3	9.1
	Mean	43.3	5.8	31.3	43.8	55.2	3.9	1.0	14.5	18.7	3.1	6.4	84.8	1.3	0.6	1.1	32.4	2.4	0.8	9.7
AV	I.	44.2	5.0	23.3	43.9	56.0	3.7	0.3	12.6	22.5	4.0	1.5	87.8	0.0	0.5	1.0	35.0	1.0	0.8	7.4
	II.	58.5	0.3	81.7	27.7	56.0	3.8	0.0	13.9	7.2	4.2	20.2	88.0	0.2	0.2	1.0	36.8	1.3	1.5	7.2
	III.	43.4	5.8	31.4	42.6	53.8	4.8	0.8	13.1	20.8	4.8	2.4	85.8	1.0	0.7	1.0	35.6	1.6	1.2	7.1
	IV.	45.2	4.8	27.2	41.8	56.8	3.2	0.0	12.7	23.2	4.6	0.2	89.8	0.0	0.0	1.0	36.4	1.0	0.8	6.2
	Mean	47.8	4.0	40.9	39.0	55.7	3.9	0.3	13.1	18.4	4.4	6.1	87.9	0.3	0.3	1.0	36.0	1.2	1.1	7.0
AP	I.	45.5	5.5	18.5	43.8	56.5	3.5	0.0	12.3	23.5	3.5	1.0	81.5	1.0	0.5	1.0	34.0	1.0	2.0	6.3
	II.	59.0	0.5	81.0	24.7	52.5	6.0	1.5	14.0	7.5	1.0	19.5	92.0	0.5	0.5	1.0	36.5	0.5	1.5	6.9
	III.	39.5	8.5	25.5	41.7	56.5	3.5	0.0	12.4	18.0	6.0	4.0	87.5	1.0	0.0	1.0	42.0	0.0	0.5	6.0
	IV.	42.0	6.5	26.0	39.5	57.5	1.5	0.0	12.2	21.0	5.0	2.0	91.5	0.0	0.5	1.1	36.0	0.0	0.5	5.7
	Mean	46.5	5.3	37.8	37.4	55.8	3.6	0.4	12.7	17.5	3.9	6.6	88.1	0.6	0.4	1.0	37.1	0.4	1.1	6.2

P=probability monitoring, A=arithmetic operations, T=target identification, W=warning light monitoring, B=blinking light monitoring, H=hits, M=misses, FA=false alarms, L=latency in sec, R=right, and W=wrong. I=first half hour, II=second half hour of high performance probe, III=third half hour, and IV= last half hour of work. AP=appetitive condition means, and AV=avoidance condition means.

was revealed by the performance decrements observed during the high performance probe.

To assess potential interrelationships between physiological status and performance effectiveness and productivity on the MTPB, the following four measures were obtained while subjects concurrently operated the performance battery: (1) heart rate, (2) frontalis EMG, (3) skin temperature, and (4) skin conductance. Tables 9, 10, 11, and 12 present these data across observational intervals identical to those used for the presentation of MTPB data. Urine free cortisol levels were also determined from analyses of total urine volume which was collected throughout the mission.[1] Table 13 presents these data for each subject across successive days of the study. The data within Tables 9-13 are, for the most part, free from notable trends over time or from effects of the two program conditions. However, that at least some measures are sensitive to transitory environmental changes are indicated by the observed decreases in skin temperature and complimentary increases in skin conductance during the high performance probe. With respect to program condition effects, the persistence of these response systems, along with the practice effects observed on the MTPB, stand in sharp contrast to the somewhat dramatic effects of the avoidance condition on other measures of intra- and interpersonal status and of performance productivity.

Despite the absence of clear condition effects on the several physiological parameters, a strong overall relationship was observed between individual MTPB productivity and mean daily urine free cortisol. Figure 5 presents these data for each subject. A direct relationship is evident between mean MTPB points per day and mean urine free cortisol per day. That is, the subject with the highest average productivity (Subject 1, omitting day 5) also shows the highest average cortisol levels. Conversely, the subject with the lowest average productivity (Subject 3) also shows the lowest average cortisol levels. Additionally, this low-productivity subject also showed the greatest disruption in performance effectiveness during the high performance probe of the MTPB, i.e., false alarms on probability monitoring and misses on target identification. More significantly perhaps, Subject 1 who shows the highest cortisol levels of any subject in the group refused to work on day 5 of the study. These observations together suggest that the stress of sustained high productivity along with prolonged performance accuracy on a demanding task may render an individual vulnerable to disruptive emotional reactions such as those provoked by the avoidance phase of the study.

Papers and Publications.

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1. These analyses were conducted by J. L. Meyerhoff and E. H. Mougey, Walter Reed Army Institute of Research, Washington, D. C.

TABLE 9

HEART RATE MEANS

		Program Conditions		
		AP	AV	AP
S1	I.	65	71	64
	II.	64	73	64
	III.	67	67	60
	IV.	67	61	59
S2	I.	72	69	67
	II.	72	70	68
	III.	71	70	67
	IV.	64	64	61
S3	I.	55	58	54
	II.	54	59	56
	III.	52	56	57
	IV.	54	55	54

I=first half hour, II=second half hour of high performance probe, III=third half hour, and IV=last half hour. AP=appetitive condition, and AV=avoidance condition.

TABLE 10

FRONTALIS EMG MEANS

		AP	AV	AP
S1	I.	4.8	4.5	6.0
	II.	5.4	5.1	5.9
	III.	4.8	4.1	3.5
	IV.	3.0	2.5	3.1
S2	I.	1.8	2.5	2.3
	II.	2.0	2.5	2.4
	III.	2.5	3.3	2.6
	IV.	3.8	4.6	3.4
S3	I.	3.6	1.2	1.6
	II.	0.9	1.2	1.3
	III.	1.0	1.2	1.4
	IV.	1.6	1.3	1.6

I=first half hour, II=second half hour of high performance probe, III=third half hour, and IV=last half hour. AP=appetitive condition, and AV=avoidance condition.

TABLE 11

SKIN TEMPERATURE MEANS

		AP	AV	AP
S1	I.	95.8	95.3	94.6
	II.	93.9	95.0	94.3
	III.	95.5	95.2	93.9
	IV.	96.0	94.4	92.0
S2	I.	92.3	92.8	93.3
	II.	89.4	91.5	92.5
	III.	91.4	91.8	94.0
	IV.	91.2	92.3	93.4
S3	I.	89.9	93.5	94.1
	II.	89.6	89.3	94.2
	III.	89.3	90.4	92.8
	IV.	82.9	88.1	89.0

I=first half hour, II=second half hour of high performance probe, III=third half hour, and IV=last half hour. AP=appetitive condition, and AV=avoidance condition.

TABLE 12

SKIN CONDUCTANCE MEANS

		AP	AV	AP
S1	I.	15.5	8.8	11.9
	II.	17.2	10.5	12.7
	III.	15.9	10.2	12.5
	IV.	11.2	8.7	10.9
S2	I.	16.5	14.8	14.5
	II.	20.8	16.8	18.1
	III.	18.0	15.8	16.2
	IV.	13.3	12.0	12.7
S3	I.	25.5	23.3	22.5
	II.	27.4	29.1	32.0
	III.	24.4	27.1	27.7
	IV.	19.5	24.7	27.4

I=first half hour, II=second half hour of high performance probe, III=third half hour, and IV=last half hour. AP=appetitive condition, and AV=avoidance condition.

TABLE 13

URINE FREE CORTISOL

	Successive Days					
	1	2	3	4	5	6
S1	76	65	64	71	56	63
S2	29	87	49	67	61	63
S3	31	47	32	40	41	45

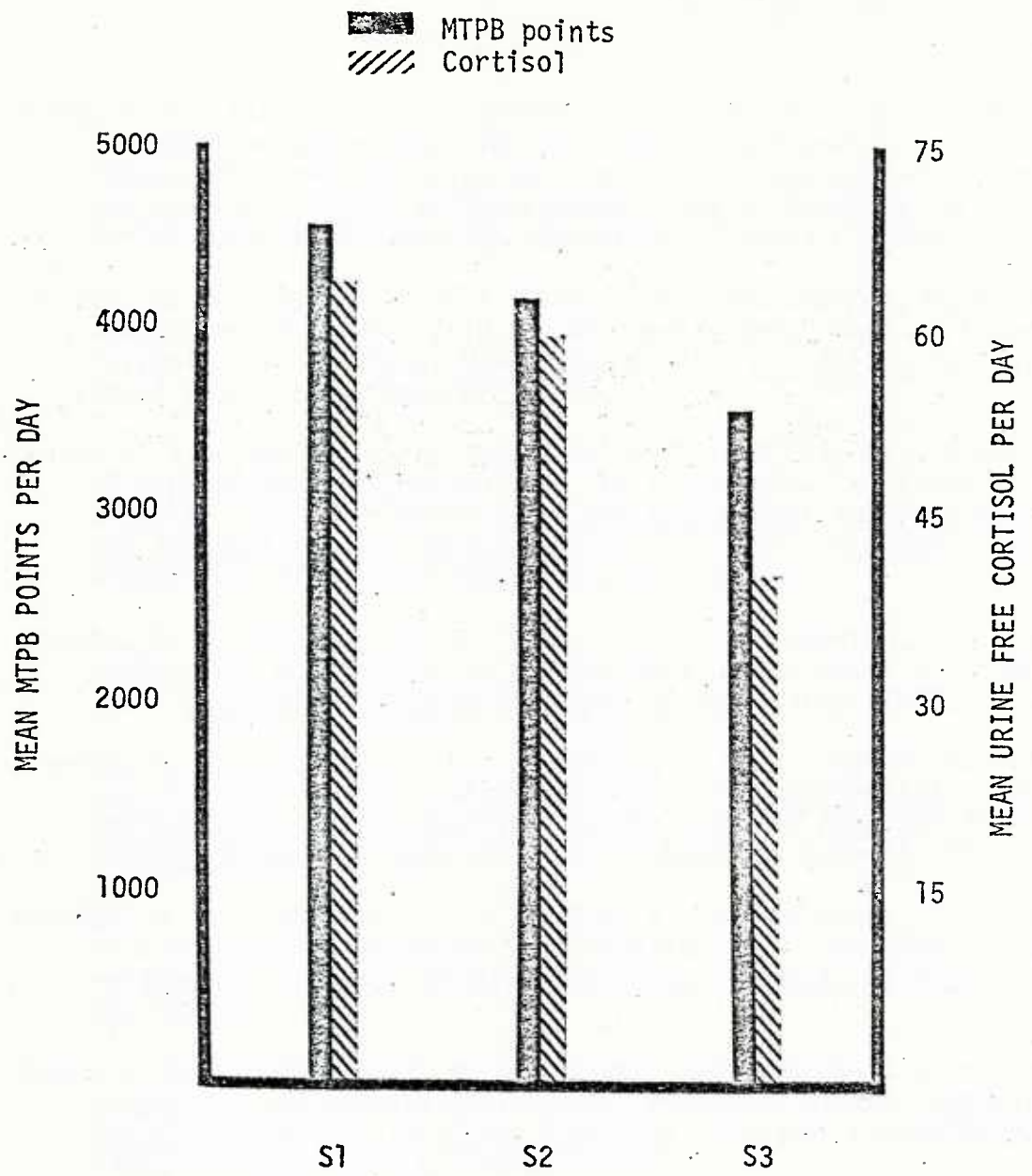

Figure 5. The relationship between mean MTPB points and mean urine free cortisol per day for each subject. Day 5 was omitted from the analysis for subject 1, but an identical relation would obtain had day 5 been omitted for all subjects.

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1030 E. Green St.
Pasadena, CA 91106

Psychologist, ONR Branch Office
1030 E. Green St.
Pasadena, CA 91106

Research Psychologist, ONR
ONR Branch Office
536 S. Clark St.
Chicago, IL 60605

Dr. Earl A. Alluisi
Old Dominion University
Research Foundation
Norfolk, VA 23508

Dr. Samuel L. Gaertner
Department of Psychology
University of Delaware
220 Wolf Hall
Newark, Delaware 19711

Dr. Irwin Sarason
Department of Psychology
University of Washington
Seattle, WA 98195

Dr. Lennart Levi, Director
Lab. Clinical Stress Research, FACK
S-104 01 Stockholm, Sweden

Dr. Edwin Hollander
Department of Psychology
State University of New York
at Buffalo
4230 Ridge Lea Road
Buffalo, NY 14226